DESCHUTES RIVER – BANK STABILIZATION PROJECTS ASSESSMENT

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1.0 Introduction

1.1 Background

The Deschutes River Conservancy (DRC) retained River Design Group, Inc. (RDG) to evaluate bank stabilization and fish habitat projects completed on the Upper Deschutes River south of Sunriver, Oregon. In addition to the DRC, the Upper Deschutes Watershed Council, Oregon Department of Fish and Wildlife (ODFW), the Deschutes National Forest (USFS), and Dr. Randy Wildman (ecologist with Oregon State University) comprise the Technical Team involved with evaluating past projects. The Technical Team provided RDG with information and experiences related to the completed projects. Assessment project tasks included reviewing completed bank projects, evaluating project success, and developing recommendations for guiding future decision making regarding bank stabilization and aquatic habitat improvement projects. The following document summarizes the project tasks.

1.2 Document Purpose and Objectives

The bank stabilization assessment was completed to evaluate bank stabilization and aquatic habitat projects that have been completed on the Upper Deschutes River since 1996. The primary project objective was to identify and discuss techniques that have proven effective in stabilizing eroding stream banks and enhancing aquatic habitat. Information collected during the assessment is intended to be used to assist future decision-making directed towards improving water quality, aquatic habitat, and bank stability on the Upper Deschutes River.

2.0 Data Collection

The Technical Team met on November 7, 2005 to discuss the various projects and to provide project-specific information to RDG.

RDG completed site visits on November 8, 21, and 22, 2005. Information provided by the Technical Team was reviewed prior to initiating each of the site visits. The following information was recorded at each site.

- Site name
- Project goals and objectives
- Project components (e.g. structure type)
- Project location relative to channel plan form
- Current site conditions
- Structure stability
- Structure function
- Vegetation condition
- Stream bank/terrace condition
- Channel and bank substrate material

Each site was photographed to characterize the current site conditions. Survey data were collected at two sites to characterize channel and floodplain features.

3.0 River Corridor Conditions and Limiting Factors

The following section reviews existing watershed conditions in the Upper Deschutes River subbasin and presents a limiting factors analysis. Existing watershed conditions information is largely derived from the *Upper Deschutes Subbasin Assessment* and the references therein (Yake, 2003).

3.1 Upper Deschutes River Corridor Conditions

The following sections present summary information concerning watershed conditions in the Upper Deschutes River subbasin. Water management, soil characteristics, vegetation conditions, and land management practices influence bank stability and aquatic habitat in the Upper Deschutes River subbasin.

3.1.1 Upper Deschutes River Water Management

The Deschutes River is a spring-fed system that historically had very stable flows that averaged 1,100 cfs. The basin's geology had an overriding influence on the hydrograph, moderating spring runoff and providing consistent base flows throughout the summer months (Yake, 2003). River engineering projects completed in the mid-1940s were implemented to improve irrigation efficiency throughout the subbasin. Crane Prairie Reservoir and Wickiup Reservoir are the primary water control features in the Upper Deschutes River basin upstream of Sunriver. Management of Crane Prairie Dam and Wickiup Dam follows water supply needs of irrigators in the subbasin. From November to March, the storage season, flows in the Deschutes River just below Wickiup Reservoir can drop to as little as 20 cfs. Peak summertime flows average 1,200 to 1,800 cfs (Yake, 2003). Contemporary water management in the Upper Deschutes River subbasin yields a hydrograph that substantially varies from the historical flow regime. Flow manipulation has a profound influence on stream bank stability, aquatic habitat conditions, and water quality of the Upper Deschutes River.

3.1.2 Soil Characteristics

The parent materials for the soils in the subbasin are primarily composed of ash, cinders, and pumice deposited from past volcanic eruptions (Yake, 2003). Volcanic-derived sediments comprising the river channel and floodplain surfaces are fine-grained materials that have low bulk density, lack cohesion, and are highly erodible. Stream bank stability is maintained by dense riparian vegetation characterized by hydrophytic sedges, rushes, and woody shrubs. Filamentous roots bind the fine soil and provide resistance to erosion.

Riparian vegetation condition is essential to maintaining bank stability on the Upper Deschutes River. Vegetation removal or loss of vegetation due to stream flow management, increases stream bank susceptibility to erosion. Accelerated bank erosion contributes fine soil to the river, increasing turbidity and degrading water quality. This process is magnified by the extreme annual flow fluctuations that have resulted in vast areas of exposed channel bed (referred to as the "drawdown" area in Yake, 2003) during the water storage season when minimal flows are released to the river. The drawdown area relates to channel area between the 30 cfs and 1,000 cfs flow levels (Yake, 2003). Freeze-thaw processes and spring water releases at the inception of the irrigation season magnify fine sediment delivery to the river.

3.1.3 Riparian Vegetation Conditions

Riparian vegetation is critical for maintaining bank stability on the Upper Deschutes River. Because riparian vegetation is influenced by flow management, high summer and low winter flows affect vegetation communities on the Upper Deschutes River floodplain. Current vegetation patterns are largely the result of high summer flows that limit vegetation encroachment into the channel. Low winter time flows may also influence vegetation patterns although this relationship appears to be weaker since the low flow period generally corresponds with plant dormancy. Aside from water management, vegetation conditions are the second most important variable affecting bank stability and aquatic habitat.

3.1.4 Land Management Practices

Historical and contemporary land management practices have influenced river corridor conditions in the Upper Deschutes subbasin. The Upper Deschutes River was historically used to transport logs from the upper watershed to downstream lumber mills. In order to facilitate the transportation of logs and prevent log-jams during the early 1900s, much of the naturally occurring large woody material was removed from the river channel between where Wickiup Reservoir is currently located to one-half mile above Benham Falls (Yake, 2003). Removal of large woody material along the river during the early part of the 20th century contributed to a lack of resistance to erosion along the stream banks (USDA, 1996 *as cited in* Yake, 2003).

Along the Upper Deschutes River in the area between Wickiup Reservoir and Pringle Falls, lodgepole pine has been thinned in several units. Roads, home sites, campgrounds, and recreational areas that receive heavy use have also displaced or otherwise impacted riparian vegetation communities.

Human population growth in the Sunriver-La Pine corridor is also impacting river conditions. Increasing residential development adjacent to the Upper Deschutes River has obvious consequences for bank stability. Conversion of native plant communities to lawns and exotic plant species displaces soil binding plants that have evolved in the Upper Deschutes River watershed. Fertilizers and herbicides applied on streamside yards have the potential to discharge to the river, affecting aquatic and riparian vegetation. Additionally, landowners dump yard clippings on stream banks as a means for disposing of unwanted materials.

An increasing number of docks, retaining walls, and other channel and floodplain manipulations also affect the river. Docks may accelerate bank erosion by deflecting flows into stream banks. Woody debris trapped in docks may be removed from the river by landowners, decreasing beneficial woody debris recruitment to downstream areas. Retaining walls, riprap, and other modified banks limit natural channel processes, displace riparian vegetation, and often degrade aquatic habitat. Other channel and floodplain manipulations that include dredging and filling the river and off-channel areas reduce aquatic and riparian habitat diversity.

Lastly, an increasing number of recreators use the river for boating. Although the river is well-posted with speed limit signs, boat wakes are an additional source of bank erosion. Boat wake impacts appear to be accentuated downstream from the Sunriver Marina and in more densely populated areas such as the Water Wonderland development where high stream banks, poor riparian vegetation conditions, and fine soils accelerate bank erosion rates.

3.2 Limiting Factors Considerations

Water management, soils composition, riparian vegetation conditions, and increasing residential development in the Upper Deschutes River subbasin present resource managers with considerable challenges for restoring river corridor conditions. The Upper Deschutes River is a highly manipulated system whereby operation of Wickiup Dam has an overriding influence on the system's hydrology. The management of flows has created the equivalent of a 25-year flood event sustained for the six-month irrigation season since the construction of Wickiup in 1949 (USDA, 1996 *as cited in* Yake, 2003). Artificial flood stages from irrigation releases have accelerated lateral erosion on the outside bends in the river and increased point bar deposition. Review of historical and recent aerial photographs suggests a 20% increase in channel width from 1943 and 1991, and an increase in the number of meander cutoffs from 2 to 12 over the same time period (USDA, 1996 *as cited in* Yake, 2003). Fine volcanic sediment, degraded riparian vegetation, and an increasing number of boats using the Upper Deschutes River accelerate sediment delivery to the river. Loss of stable large woody debris from the system has also reduced bank protection and sediment storage capacity.

These issues must be taken into account by managers when planning bank stabilization and aquatic habitat improvement projects. Over the long-term, addressing how water is managed in the basin will be imperative for restoring the Upper Deschutes River from its current state as an irrigation canal to its historical condition as a functioning river supporting fish, wildlife, and high quality water. Because returning river flows to a more natural pattern is expected to require considerable negotiations among the primary water users in the basin, more immediate steps may be taken to reverse water quality and aquatic habitat degradation that currently affect the river corridor.

While water management affects channel morphology and vegetation conditions, fish population data suggest flow management also has a negative impact on the fish community especially in the reach downstream from Wickiup Dam (Steve Marks, ODFW biologist, personal communication). Anticipated irrigation season flow management impacts on fish habitat include (ODFW, 1996 *as cited in* Yake, 2003):

- Increases in the rate of bank erosion and sediment load. Higher flows are causing changes in the meander sequence of the river.

- Spawning gravels are moved to stream margins and become embedded with finer sediment. Flow regulation has eliminated the short-term spring “flushing” flows that clean spawning gravel under natural flow conditions.
- Increased bank erosion and sedimentation makes it difficult to maintain riparian and aquatic vegetation and breaks down the chain of primary food production, especially aquatic insects and the vegetation they depend on.
- Inundation of stream banks during the growing season impacts growth of vegetation.

During the water storage period, fish habitat is impacted by the low flow releases through the following processes (ODFW, 1996 *as cited in* Yake, 2003):

- Exposure of spawning redds.
- Reduction in winter time cover.
- Loss of aquatic invertebrate production due to channel dewatering.
- Concentration of trout in a few deeper pools, increasing their vulnerability to predation and harvest.
- Increased ice-induced mortality of trout during severe cold periods when the channel freezes.
- Dewatering of adjacent wetlands and riparian areas whish provide trout food and cover.
- Exposed stream banks experience freeze-thaw action resulting in breakdown and eventual soil loss when flows are increased during the irrigation season.
- Increased foot access to river sections not fishable at high water levels and concurrently reduces the ability to boat the river.

3.3 Summary

Water management in the Upper Deschutes River subbasin impacts channel morphology, vegetation condition, and biological communities. Accelerated bank erosion, diminished riparian vegetation, and degraded aquatic habitat are related to the high flows during the summer irrigation season, and the low flows maintained during the winter storage season. Although the river system will continue to be hampered until the water management system is modified, there are opportunities for improving bank stability and aquatic habitat in the short-term.

4.0 Bank Stabilization and Aquatic Habitat Improvement Projects

4.1 Bank Stabilization and Aquatic Habitat Improvement Projects Overview

Eleven project sites spanning from Wickiup Dam downstream to the Sunriver Marina area were evaluated in November 2005. Projects date to 1996, but were mainly completed between 2000 and 2005. Projects generally consisted of placing large wood to provide bank protection and aquatic habitat. Wood was placed in two configurations: as single pieces and as more complex multi-piece structures. Riparian plantings were often completed to improve long-term bank stability, provide riparian habitat, and eventually contribute woody debris to the river. The degree of sediment deposition related to the structures was often difficult to determine as features that appeared to be depositional could have been remnant floodplain surfaces that had eroded over time. However, deposition on trees and other debris was used as an indication of structure influence. The influence of structures on sediment deposition was evaluated where possible.

The following sections summarize field observations made during the site visits.

4.2 Reach 1: USFS Projects Downstream from Wickiup Dam

Three projects completed by the USFS were the most upstream projects reviewed. Completed in 2002, the project are located approximately 0.5 miles downstream from Wickiup Dam and treated nearly 1,200 ft of channel banks. Project goals for the three sites included narrowing and deepening the channel, reducing bank erosion, and improving the riparian condition. The following sections present observations on how the three projects are functioning.

4.2.1 Reach 1-1: Former Boat Access

Project Overview

The most upstream of the three projects was intended to stabilize and revegetate an eroding bank formerly used by recreators as a boat launch. The project is located on a straight section of the channel upstream of a transition to a pool. Project site characteristics are included in Table 4-1. An eroding unvegetated bank characterized the project site. Bank erosion and surface runoff from the unvegetated slope contributed fine sediment to the channel. Poor aquatic habitat was related to the degraded riparian vegetation condition and lack of large woody debris.

Table 4-1. Site characteristics for Reach 1-1.

Project Site	Bankfull Width (ft)	Wetted Width (ft)	Project Length (ft)	Pieces of Woody Debris in Project
Reach 1-1	150 ft	60 ft	180 ft	18+

The project goals included narrowing the channel width, reducing bank erosion, and improving the riparian vegetation condition. Project construction included the following tasks.

- Re-grading of the eroding bank.
- Large woody debris placement and anchoring.
- Sedge mat transplants.
- Planting of willow and spirea cuttings along the channel margin and planting of pines on the terrace.

The large wood was placed singularly as well as in two triangular arrays (similar to a barb in plan view) intended to deflect flows away from the stream bank (Figure 4-1). Fill was placed inside of the triangular arrays and sedge mats were placed on the fill. Boulders were placed around the woody debris to anchor the material. Willow and spirea cuttings were placed at the toe of the re-graded slope.

Figure 4-1. Reach 1-1 site conditions looking upstream towards Wickiup Dam. The left photo shows the length of the project site. The right photo focuses on the triangular barb in the middle of the first photo. Note minimal sediment deposition and coarser gravels dominating the channel substrate.

Structure Function and Stability

The large wood project continues to function although structure stability has diminished. Although the structures have not narrowed or deepened the channel, the re-graded bank does not appear to be actively eroding. The barbs have eroded and only a remnant of the planted sedge mats remains. The wood structures have captured pieces of small woody debris, but minimal sediment deposition has occurred downstream of the structures. Coarser bed material (up to 90 mm particle size) and minimal deposition suggest the influence of the upstream dam on the available sediment load. The lack of fine sediment around the structures suggests Wickiup Dam traps fine sediment that would otherwise be available to the Upper Deschutes River downstream from Wickiup Reservoir. Deposition observed in downstream reaches confers the influence of the dam on the sediment load is fairly localized.

The structures provide aquatic habitat during high flows, but do not interact with the wetted channel during winter base flows. Therefore, the project does not benefit fish during the critical winter water storage period.

Evaluation of Project Success and Contributions to Improving Future Projects

The project is not meeting all of the project goals as the structures have not modified the channel morphology. The sedge mats have been eroded and the underlying wood is now exposed. Willow and spirea cuttings did not survive. Despite these problems, the former bank erosion appears to have been halted by the project and the structures provide fish habitat during the irrigation season.

The project offers several examples for improving future projects. First, it was unlikely that the project would effectively influence the channel morphology due to the small footprint of the project and the limited channel modification that took place during the original project construction. Because the channel bed material is characterized by both clay hardpan and coarser gravels, a substantial constriction of the channel would be necessary to generate the shear stress required to scour the channel. Similarly, because the project is located downstream from Wickiup Dam, there is minimal bedload or suspended load moving through the reach. This minimal bedload limits the possibility of channel margin deposition that would influence the channel width.

Secondly, the sedge mats placed on the woody debris barbs were set too low in the channel cross-section profile. The low elevation resulted in sedge drowning during the irrigation season. The cuttings were similarly affected by the high summer flows. Surveying downstream and across-channel reference sedge surfaces to determine the range of elevations that native sedges were growing, would have increased the likelihood of sedge and willow cutting survival. Constructing a more continuous bench and planting the sedge mats at a more appropriate elevation would have improved stream bank resistance to lateral channel scour and frost heaving that will likely continue to contribute sediment to the channel.

Lastly, setting the woody debris lower in the channel cross-section profile or using longer trees would have provided aquatic habitat over the entire hydrograph. Although the project does provide habitat during high flows, the woody debris does not interact with the low flow channel. Additionally, building denser structures with a greater volume would provide more diverse aquatic habitat.

In summary, the USFS project has reduced active bank erosion and improved high stage fish habitat in the treated reach. The project also offers several lessons for improving future projects including setting the woody debris structures and vegetation at appropriate elevations to improve the likelihood of success.

4.2.2 Reach 1-2: Eroding Terrace – West Bank

Project Overview

The middle of the three USFS projects was intended to stabilize and revegetate an eroding terrace on the west side of the channel. The project is located on the outside of the meander and across from the upstream USFS project (Reach 1-1). Project site characteristics are included in Table 4-2. An eroding vertical terrace characterized the project site. Poor aquatic habitat was related to the degraded riparian vegetation condition and lack of large woody debris.

Table 4-2. Site characteristics for Reach 1-2.

Project Site	Bankfull Width (ft)	Wetted Width (ft)	Project Length (ft)	Pieces of Woody Debris in Project
Reach 1-2	150 ft	60 ft	700 ft	19

The project goals included narrowing the channel width, reducing bank erosion, and improving the riparian vegetation condition. Project construction included the following tasks.

- Re-grading the eroding terrace.
- Bankfull bench construction at the toe of the eroding terrace.
- Large woody debris placement and anchoring.
- Sedge mat transplants.

- Planting of willow cuttings on the bankfull bench.

The vertical terrace was sloped and a 10 – 12 ft wide bankfull bench was constructed at the toe of the slope (some or all of the bench may have existed prior to the project). Sedge mats and willow cuttings were planted on the bankfull bench. A whole tree was placed perpendicular to the bank in the upstream portion of the project. Additional whole trees were interconnected and placed parallel to the bank to provide toe protection.

Figure 4-2. Reach 1-2 site conditions looking downstream from the top of the project. The large tree placed at the upstream extent of the project is collecting woody debris (left). Whole trees placed parallel to the banfull bench provide resistance toe scour although the sedge mats have been eroded from the bench.

Structure Function and Stability

The large wood project continues to function as intended. The leading whole tree is trapping smaller woody debris and provides bank protection. The additional whole trees continue to provide bench stability. Although channel cross-section survey data suggest the channel width has returned to the pre-project channel width, the stable bench would suggest the channel is narrower now than prior to the project. Similar to the Reach 1-1 project, fine sediment deposition in the project area was minimal. The re-graded terrace continues to erode through frost heaving and particle detachment. Frost heaving on the bankfull bench also destabilizes soil in the project area.

The structures provide aquatic habitat over all flows. Whole trees provide diverse microhabitats along the channel margin that previously was a simplified slope. Channel scour and vertical pool habitat formation do not appear to have been improved by the woody debris structures.

Evaluation of Project Success and Contributions to Improving Future Projects

The project does appear to satisfy the project goals except for site revegetation. The sedge sod mats have been eroded and the bankfull bench is now exposed. Willow cuttings survival is minimal to non-existent. Although erosion of the re-graded terrace face contributes minor amounts of clay to the river, the woody structures at the toe of the slope appear to otherwise stabilize the bench.

The project offers several examples for improving future projects. First, the sedge mats placed on the bankfull bench were set too low in the channel cross-section profile. The low elevation resulted in sedge drowning during the irrigation season. The cuttings were similarly affected by the high summer flows.

Placing more of the wood perpendicular to the channel would have increased woody debris interaction with flows, providing more fish habitat over the hydrograph. Stable large wood could also promote vertical channel scour and improve pool depths.

In summary, the USFS project has reduced active terrace erosion and improved fish habitat over all flows in the treated reach. The project also offers several lessons for improving future projects including setting vegetation at the appropriate elevation to improve the likelihood of site revegetation. Orienting large wood perpendicular to the flow would also improve fish habitat.

4.2.3 Reach 1-3: Eroding Terrace – East Bank

Project Overview

The lower of the three USFS projects was intended to stabilize and revegetate an eroding terrace on the east side of the channel. The project is located on the outside of the meander at the transition from a pool to a riffle. Reach 1-3 is downstream from the middle USFS project (Reach 1-2). Project site characteristics are included in Table 4-3. An eroding vertical terrace characterized the project site. Poor aquatic habitat was related to the degraded riparian vegetation condition and lack of large woody debris.

Table 4-3. Site characteristics for Reach 1-3.

Project Site	Bankfull Width (ft)	Wetted Width (ft)	Project Length (ft)	Pieces of Woody Debris in Project
Reach 1-3	96 ft	72 ft	360 ft	10+

The project goals included narrowing the channel width, reducing terrace erosion, and improving the riparian vegetation condition. Project construction included the following tasks.

- Re-grading of the eroding terrace.
- Bankfull bench construction at the toe of the eroding terrace.
- Large woody debris placement and anchoring.
- Sedge mat transplants.
- Planting of willow cuttings on the bankfull bench.

The vertical terrace was sloped and a 6-10 ft wide sloping bankfull bench was constructed at the terrace toe. Sedge mats and willow cuttings were planted on the bankfull bench. Whole trees were generally placed at 45° from the bank in an upstream direction. While some of the trees were anchored with cables, large rock was also used to stabilize the trees.

Figure 4-3. Reach 1-3 site conditions. Large wood was placed perpendicular to flow and interacts with the low flow channel (left). Whole trees provide aquatic habitat during low flows (right).

Structure Function and Stability

Of the three USFS projects, Reach 1-3 is the most functional and appears to be satisfying the project goals. The whole trees trap woody debris and interact with all flow stages to provide aquatic habitat. Sedge mats placed on the bench were set at an appropriate elevation and remain viable. Soil dislodged from the adjacent terrace is trapped by the stable sedges, buffering the river from additional sediment delivery. Willow cuttings planted at the toe of the terrace have greater survival than at the other two projects suggesting a more appropriate planting elevation. Minimal sediment deposition behind the woody debris structures is likely related to reservoir trapping of fine sediment.

Evaluation of Project Success and Contributions to Improving Future Projects

This project is meeting the project goals of reducing terrace erosion, improving riparian vegetation condition, and enhancing aquatic habitat. The bankfull bench is stable and vegetated by sedge mats and willow cuttings. Placed wood interacts with the low flow channel and provides bank stability.

Although the project is largely functioning as intended, several modifications could be made to further improve future projects. First, the bankfull bench could be expanded to increase the surface for riparian vegetation. A wider bench would expand the vegetated buffer separating the terrace from the river.

Placing more wood perpendicular to the channel would have increased woody debris interaction with the river, providing more fish habitat over the hydrograph. Stable large wood could also promote vertical channel scour and improve pool depths. Constructing jams rather than placing single or a few trees together would increase habitat diversity and bank protection.

In summary, the USFS project has reduced active terrace erosion and improved fish habitat over all flows in the treated reach. The project also offers several lessons for improving future projects including setting vegetation at the appropriate elevation to improve the likelihood of site revegetation. Orienting large wood perpendicular to the flow also improves fish habitat.

4.3 Reach 2: Pringle Falls Reach

Project Overview

A meander upstream from the Pringle Falls Loop Bridge was visited to evaluate large woody debris on the Upper Deschutes River floodplain. The USFS/ODFW project located downstream of Pringle Falls was not visited. It is not believed that the visited site was part of the Pringle Falls project completed by USFS and ODFW, although the tree locations suggest it was a constructed project. The project site was characterized by a well-vegetated floodplain, whole trees interacting with the low flow channel, and stable banks. Site characteristics for Reach 2 are included in Table 4-4. A site photograph is included in Figure 4-4.

Table 4-4. Site characteristics for Reach 2.

Project Site	Bankfull Width (ft)	Wetted Width (ft)	Project Length (ft)	Pieces of Woody Debris in Project
Reach 2	110 ft	75 ft	400 ft+	20+

Figure 4-4. Reach 2 site conditions are characterized by large wood perpendicular to the channel on the outside of a channel meander. Woody debris at this site appears to have been placed.

Structure Function and Stability

The whole trees are stable, collecting fine sediment and woody debris, and interacting with the low flow channel. The well-vegetated floodplain buffers the adjacent terrace from the river. Comparatively, a high terrace downstream from the reviewed site is interacting with the river and contributing sediment. The floodplain bench buffering the terrace at the reviewed site is a good model of a functioning floodplain surface.

The whole trees are stable and interact with the river over all stages of the hydrograph. Individual trees have not clustered to form more substantial jams. Over time, as trees migrate down the channel, jam formation is expected.

In summary, the stable whole trees dominating the site provide insights for improving future bank stabilization and fish habitat projects. Orienting large wood to interact with the channel increases fish habitat benefits and improves sediment storage potential. The vegetated floodplain is a model for designing similar surfaces. The floodplain buffers the adjacent terrace from the laterally migrating river.

4.4 Reach 3: La Pine State Park

Project Overview

The La Pine State Park reach extended from the La Pine State Park Road Bridge upstream approximately 0.5 miles. The project reach is downstream of Pringle Falls and upstream of the Fall River confluence. Channel conditions vary through the reach (Figure 4-5). In general, outside meanders are characterized by high eroding terraces. Inside meanders and straight channel reaches typically had vegetated floodplains separating the channel from adjacent terraces. Channel margin conditions ranged from raw banks with minimal large wood, to vegetated surfaces with stable large wood and stored fine sediment.

Figure 4-5. Varied channel conditions in the La Pine State Park reach. High terraces are actively eroding and infrequent woody debris accumulations lead to poor aquatic habitat and riparian vegetation (left). Stable straight reaches support vegetated floodplain surfaces and stable large wood (right).

Whole trees were placed on both sides of the river via helicopter. Although tree locations varied, most pieces generally spanned from the high bank, across a narrow floodplain bench, and intercepted the channel. Project site characteristics at the downstream end of the reach are included in Table 4-5.

Table 4-5. Site characteristics for Reach 3.

Project Site	Bankfull Width (ft)	Wetted Width (ft)	Project Length (ft)	Pieces of Woody Debris in Project
Reach 3	120 ft	78 ft	0.5+ miles	100+

The project goals included adding whole trees to the project area to improve fish habitat and sediment storage.

Structure Function and Stability

Wood placed in the La Pine State Park reach is functioning to varying degrees. While single pieces affect localized sediment deposition and fish habitat conditions, larger jams formed through accumulations of large wood are more stable and provide greater habitat benefits. Two large jams exhibited a strong influence on downstream sediment deposition with sediment depositing to nearly 75% of the jam height. Figure 4-6 illustrates the role of a large woody debris jam on sediment transport. The left photo shows the jam with an extended area of deposited sediment downstream from the jam. The right photo shows the river channel and terrace immediately upstream from the jam. While the upstream reach is characterized by an over-widened simplified channel, the channel adjacent to the jam is being narrowed and has more diverse aquatic habitat created by the jam. Over time as sediment deposition continues, a floodplain surface may form as vegetation colonizes the deposit.

Figure 4-6. A substantial woody debris jam influences sediment deposition and provides fish habitat (left). The channel upstream from the jam is over-widened and has simplified low flow aquatic habitat (right).

Woody debris jams appear to have the greatest influence on channel morphology, sediment deposition, and aquatic habitat. Compared to individual pieces of wood, jams are more stable and will continue to grow in size over time as they collect more material and wood is anchored by accumulating sediment. As a jam's volume increases, so will the jam's interaction with the channel. Figure 4-7 shows two other jams observed in the La Pine State Park reach. These jams are formed by aggregated trees that were likely individually placed in the upstream channel. The photos illustrate the influence of the jams on accumulating large wood, affecting sediment deposition, and providing stable aquatic habitat.

Figure 4-7. The role of woody debris jams in affecting fine sediment deposition (left) and capture of large woody debris along channel margins (right).

Evaluation of Project Success and Contributions to Improving Future Projects

The La Pine State Park project exemplifies a more passive approach to large wood introduction to the river network. Whole trees were individually placed in the river by helicopter. Trees were not anchored and so have been free to move. While some trees have remained where originally placed, others have aggregated as jams. These jams exemplify the greatest influence of wood on channel form and aquatic habitat diversity.

In summary, these naturally-formed jams offer a template for constructing engineered debris jams. Incorporating long trees in these jams to interact with the low flow channel would further increase aquatic habitat value.

4.5 Reach 4: La Pine State Park – Old Cabin Site

Project Overview

The La Pine State Park – Old Cabin Site is located upstream of the Fall River confluence on the west side of the river. The project was completed by ODFW in 2005. Prior to the project, the site was characterized by an eroding terrace interacting with the river at the outside of an extended meander. A well-vegetated floodplain is located upstream, downstream, and across the river from the eroding terrace. Project site characteristics are included in Table 4-6.

Table 4-6. Site characteristics for Reach 4.

Project Site	Bankfull Width (ft)	Wetted Width (ft)	Project Length (ft)	Pieces of Woody Debris in Project
Reach 4	175 ft	72 ft	450 ft	50+

The project goals included reducing terrace erosion, improving the riparian vegetation condition, and creating more diverse aquatic habitat. Project construction included the following tasks.

- Re-grading the eroding terrace.
- Large woody debris placement.
- Willow containers planted on the sloped terrace.
- Ponderosa pine containers planted on disturbed upland areas.

The vertical terrace was moderately sloped prior to placing the large wood. A floodplain bench was not constructed adjacent to the sloped terrace. Whole trees and logs were placed at varying angles with trees paralleling the bank as well as intercepting the low flow channel (Figure 4-8). Trees did not appear to be anchored with rock or cables. Trees were trenched into the sloped terrace as well as overlayed on each other to increase structure stability. Willows were planted at the top of the sloped terrace. Whole trees will provide diverse aquatic habitat over the full range of flows. Upstream and downstream of the project, the terrace grades to a vegetated floodplain (Figure 4-9).


Figure 4-8. A view of the upstream end of the project shows the well-vegetated floodplain in the distance and treated bank in the foreground (left). The lower half of the project showing large wood placed on the re-graded terrace (right).

Figure 4-9. A view of the downstream end of the project showing the old cabin and the transition from the terrace to the vegetated floodplain (left). Downstream of the project area, a debris jam has formed at the mouth of a short avulsion channel (right). A willow/sedge community characterizes floodplain vegetation in the distance.

Structure Function and Stability

The recently constructed project offers an opportunity to evaluate structure function and large wood retention into the future. This project took an approach similar to the Rotz project (Reach 5) in that large wood was placed on the front of a sloped terrace along the entire bank length. This strategy differs from naturally formed jams that were observed in the La Pine State Park reach whereby jams formed more distinct units and generally formed perpendicular to flow. Natural jams also influenced sediment deposition in the downstream shadow of the jam. It is unclear how the Old Cabin bank treatment will affect fine sediment deposition. Placement of the wood without anchoring will also provide information on the trees' propensity to mobilize during the high stage summer irrigation period.

Evaluation of Project Success and Contributions to Improving Future Projects

The Old Cabin project applies some new techniques as well as more practiced methods for stabilizing an eroding terrace. Placement of a large quantity of whole trees provides a buffer to the eroding terrace and has improved aquatic habitat diversity through the meander. Several trees were placed perpendicular to the channel, thereby increasing the aquatic habitat space during low winter storage flows. Rather than using large rock or cable to anchor the trees, trees were interlaced or overlayed on one another to improve structure stability. Monitoring the materials through the first two irrigation seasons (at a minimum) is recommended to determine structure stability.

Another consideration for the Old Cabin project is the availability of large wood from upstream reaches. Over time, if the placed wood is mobilized and new wood is not recruited, the site may revert to the former eroding terrace since a floodplain bench was not constructed between the terrace and the channel. The floodplain bench established at the appropriate elevation (e.g. the upstream floodplain shown in Figure 4-8) would provide a surface that could be colonized by riparian vegetation. Dense sedge communities stabilizing a low bank height floodplain appears to be the most successful at stabilizing banks in the Upper Deschutes River. A well-vegetated floodplain would be expected to provide long-term bank stability.

In summary, the Old Cabin project used a greater number of whole trees per foot of bank than other reviewed projects. Trees were placed both perpendicular and parallel to the bank to provide bank protection and low stage aquatic habitat. Tree stability should be monitored to evaluate wood retention and wood influence on the channel.

4.6 Reach 5: Rotz Property

Project Overview

The Rotz property is located downstream from the Fall River confluence. The project site is on the west side of the river and is downstream from a riprap bank. The site was formerly characterized by a high eroding terrace on the outside of a channel meander. Ponderosa pines and bunch grasses typify the vegetation community. Project site characteristics are included in Table 4-7.

Table 4-7. Site characteristics for Reach 5.

Project Site	Bankfull Width (ft)	Wetted Width (ft)	Project Length (ft)	Pieces of Woody Debris in Project
Reach 5	138 ft	75 ft	215 ft	28

The project goals included reducing terrace erosion, creating more diverse aquatic habitat, and promoting site vegetation. Project construction completed in 2002 included the following tasks.

- Re-grading the eroding terrace.
- Large woody debris placement.

The vertical terrace was moderately sloped prior to placing the large wood. A floodplain bench was not constructed adjacent to the sloped terrace. Whole trees and logs were placed at varying angles with trees in the upper half of the project oriented in an upstream direction (Figure 4-10). Trees in the lower half of the project were placed in a downstream orientation. Trees were anchored together with cables. Tree placement provides diverse aquatic habitat and overhead cover for fish during all flow stages. There was minimal deposition within the woody debris complex. It is unclear whether vegetation was planted.

Figure 4-10. A view of the upstream end of the project shows the upstream property's riprap bank and the large wood placed in the upper end of the Rotz project (left). The lower half of the project has created over hanging cover for fish. Terrace erosion appears to be continuing downstream of the project (right).

Structure Function and Stability

The structure appears to be stable based on the large amount of wood remaining in the structure. However, as was discussed in the Old Cabin site description, a bankfull bench was not constructed adjacent to the eroding terrace. This may result in future terrace erosion once the woody debris has degraded. Erosion appears to be taking place downstream of the project until the terraces grades into the floodplain where the pool transitions to the riffle. The vegetation condition on the re-graded terrace face remains poor. Promoting vegetation growth on the terrace would improve the site's long-term stability.

Evaluation of Project Success and Contributions to Improving Future Projects

The Rotz project remains stable although the long-term success of the project is questionable due to the poor riparian condition. The whole trees placed in the channel and along the bank are buffering the terrace from erosion and providing diverse aquatic habitat. Cabling the trees together has retained the large wood on-site and reduces the possibility of future tree loss.

The poor riparian vegetation condition again points to the importance of a comprehensive planting plan for maintaining long-term bank stability. The landowner appears to also be dumping yard clippings on the bank. Although this may be harmless, yard clippings could be introducing herbicides or fertilizers to the river as well as affecting natural recruitment of vegetation on the terrace slope.

In summary, the Rotz project has improved aquatic habitat and reduced terrace erosion. Relative to the upstream riprap bank, the placed wood is more natural in appearance and likely offers better habitat. Planting vegetation on the terrace face is recommended.

4.6.1 Reach 6: Oldham/Moreland Property

Project Overview

The Oldham and Moreland property site is located in the Water Wonderland development upstream from the Little Deschutes River confluence. The site is on the east side of the river and is on an island formed by a backwater channel that connects with the Deschutes River. An eroding terrace formerly characterized the site. Terrace erosion is attributed to hydrograph fluctuations and boat wake erosion. This reach of the river experiences high summer time recreational use from boats. Two boat docks are located on the site. Project site characteristics are included in Table 4-8.

Table 4-8. Site characteristics for Reach 6.

Project Site	Bankfull Width (ft)	Wetted Width (ft)	Project Length (ft)	Pieces of Woody Debris in Project
Reach 6	168 ft	84 ft	400 ft	20+

The project goals included reducing terrace erosion and improving the riparian vegetation condition. Project construction completed since 1996 has included the following tasks.

- Re-grading the eroding terrace.
- Large woody debris placement in the form of triangular barbs and individual pieces.
- Filling the triangular barbs with small wood and soil.
- Planting the triangular barbs and the channel margin with sedges transplanted from the point bar floodplain.

On the Oldham property (located downstream from Moreland) whole trees were placed in the channel and filled with small woody debris and soil (Figure 4-11). Although the downstream barb does not appear to have been planted, the upstream barb and other portions of the channel were planted with sedges harvested from the across-river floodplain. The terrace was re-graded and trees were placed in the bank to improve bank resistance to scour. Mulch was placed over the trees and willows have been planted along the lower terrace slope. Sedges placed at the appropriate elevation have survived and colonized other areas of the channel margin.

Figure 4-11. A view of the upstream triangular barb filled with small wood and soil (left). Sedges planted at the appropriate elevation have spread along the channel margin and improved soil stability (right).

Similar techniques were used on the Moreland property. A barb was built at the upstream extent of the Moreland property at the head end of the backwater channel. Mr. Moreland has added wood to the structure over time. Fine sediment has deposited behind the structure and vegetation has colonized the deposited material (Figure 4-12). Although the wood provides high stage fish habitat, it does not interact with the low flow channel. Willows planted at the toe of the sloped terrace continue to do well.

Figure 4-12. The upstream barb has captured sediment and provides bank stability (left). Sedges planted at the appropriate elevation have prospered and colonized onto the deposited sediment trapped downstream of the barb.

Structure Function and Stability

The landowners continue to maintain the bank stabilization projects completed on their property. The whole tree triangular barbs provide a planting surface and promote downstream sediment deposition. Deposition appears to be the greatest downstream from Mr. Moreland's upstream barb. As he has added wood to the structure over time, the elevation of sediment deposition has increased. Sedge transplants were placed at an appropriate elevation and have spread along the channel margin especially over the past 2 years.

Evaluation of Project Success and Contributions to Improving Future Projects

The structures are functioning as intended and bank erosion has been halted in the project area. Similar to other reviewed projects, the sedge growth pattern is predictably based on both high water stage and bank elevation. The narrow band of sedges is controlled by summer time inundation and the droughty nature of the volcanic soils characterizing the terrace. Planting the sedges at the appropriate elevation and promoting sediment deposition with complex wood structures are critical for establishing riparian vegetation on the Upper Deschutes River. The constructed barbs function similarly to the naturally occurring debris jams reviewed in the La Pine State Park reach, suggesting the benefits of individual complex wood structures instead of many single trees set at low densities.

4.7 Reach 7: Sunriver Airport Site

Project Overview

The Sunriver Airport site is located on the east side of the river upstream from the Sunriver Airport and downstream from the Little Deschutes River confluence. The site is located at the outside of a meander adjacent to the Sunriver walking trail. Prior to the project, the bank was likely eroding and offered poor aquatic habitat. Channel characteristics are included in Table 4-9.

Table 4-9. Site characteristics for Reach 7.

Project Site	Bankfull Width (ft)	Wetted Width (ft)	Project Length (ft)	Pieces of Woody Debris in Project
Reach 7	138 ft	115 ft	100 ft +	10+

The project goals included reducing terrace erosion, improving the riparian vegetation condition, and improving aquatic habitat. Project construction included the following tasks.

- Whole tree placement and anchoring.
- Willow cutting planting.

Whole trees were generally placed perpendicular to the channel with most of the trees interacting with the low flow channel (Figure 4-13). Willow cuttings were placed near the top of the sloped bank. Sedges have colonized the site. It is unclear whether the sedges were planted or if they are volunteers.

Figure 4-13. The Sunriver Airport site is characterized by whole trees extending into the channel (left). The upstream half of the project has more recent sediment deposition and a lower riparian vegetation condition (right).

Structure Function and Stability

The placed trees are stable, collecting sediment, and protecting the adjacent bank. Vegetation is colonizing depositional areas and willow cuttings are doing well along the sloped bank. Whole trees oriented into the channel provide aquatic habitat and promote sediment deposition.

Evaluation of Project Success and Contributions to Improving Future Projects

The river through this reach is narrower than in downstream reaches. Floodplain vegetation is characterized by a sedge community. On the stabilized bank, sedges have colonized the surface. In upstream areas, deposited sediment is not vegetated. It is most likely that this surface remains too low relative to the high water stage to support vegetation. Over time as more sediment deposits downstream of the whole trees, sedges are expected to colonize the site.

This project illustrates the benefits of orienting whole trees perpendicular to the bank and intercepting the low flow channel. While it is unclear whether the sedges are naturally occurring or were planted, their colonization suggests the benefits of building a floodplain surface at an appropriate elevation. The vegetated surface now buffers the low terrace adjacent to the river. Propagating sedges will likely spread up the bank over time, enhancing the riparian condition.

4.8 Reach 8: Sunriver Marina Site

Project Overview

The Sunriver Marina site is located adjacent to and downstream from the Sunriver Marina. The treatment site is located downstream from the Little Deschutes River confluence. Bank treatments are located on both the west (upstream site) and east (downstream site) banks. Treatments were focused on two subsequent outside meanders. Channel characteristics through the reach are included in Table 4-10.

Table 4-10. Site characteristics for Reach 8.

Project Site	Bankfull Width (ft)	Wetted Width (ft)	Project Length (ft)	Pieces of Woody Debris in Project
Reach 8	240 ft	90 ft	500 ft +	90+

The project goals included reducing terrace erosion, improving the riparian vegetation condition, and improving aquatic habitat. Project construction included the following tasks.

- Re-grading one terrace.
- Whole tree placement and anchoring.
- Willow cutting planting.

At both sites, whole trees were placed both perpendicular and parallel to the bank. On the upstream site, the eroding banks did not appear to be sloped prior to tree placement (Figure 4-14). The low terrace was sloped at the downstream site prior to tree placement (Figure 4-15). Willow cuttings were placed on the sloped bank at the downstream site.

Figure 4-14. The upstream Sunriver Marina site was stabilized with large wood (left). The bank does not appear to have been sloped prior to wood placement and continues to erode (right).

Figure 4-15. The downstream Sunriver Marina site begins at the transition from the floodplain to a higher terrace (left). Individual whole trees were placed in the channel at varying angles to the bank (right).

Structure Function and Stability

The placed trees generally remain stable through both project sites. Since the trees are cabled, they will likely remain stable into the future. Smaller woody debris is recruiting to both project sites. The perpendicular orientation of the wood and accumulations of wood, have promoted sediment deposition at the downstream site (Figure 4-16). Fish were seen adjacent to several of the trees that intercept the channel.

Figure 4-16. Sediment storage in the vicinity of placed trees (left). Sedges have colonized deposited sediment at the toe of the sloped low terrace (right). Successful willow cuttings are located near the top of the low terrace bank.

Geomorphic features and vegetation were surveyed at the downstream site. The survey focused on sediment deposition, the sedge surface, surviving willows, and the top of the bank (Table 4-11). A benchmark established during a 2004 survey completed at the site was used to compare the 2004 and 2005 survey data. This is important as the 2004 survey was completed during the summer irrigation season. Using the same benchmark allows a comparison of the survey data collected in 2005 and the high water surface elevation surveyed in 2004. The high flows are believed to have a greater influence than winter time low flows on the sedge community and sediment deposition. Through the lower site, there was a 3.8 ft drawdown from the 2004 high flow water surface to the 2005 low stage.

The lowest sedge surface was located approximately 1.2 ft below the 2004 water surface. Unvegetated sediment deposits ranged from 1.4 ft to 2.8 ft below the high water elevation and 0.2 ft deeper than the lowest sedge elevation. The data suggest that as more sediment deposits downstream from the placed wood, sedges should colonize the areas as they increase in elevation. Surviving willows range from 0.3 ft to 2.3 ft above the high water line, suggesting a fairly narrow 2 ft range for successful willow planting.

Table 4-11. Survey data collected on the lower Sunriver Marina site comparing geomorphic and vegetation elevations to the high stage water surface maintained during the irrigation season.

2004 Instrument Height	1007.94 ft	
2005 Instrument Height	1006.37 ft	
Feature	Elevation Range (ft)	Difference From the High Water Surface (ft) (- is below high water stage, + is above high water stage)
2004 High Stage Water Surface	998.7	0
2005 Low Stage Water Surface	994.9	-3.8
2005 Sediment Deposit	997.3 – 996.0	-1.4 to -2.8
2005 Sedge Surface	998.1 – 997.6	-0.7 to -1.2
2005 Surviving Willow Cuttings	1001.1 – 999.1	+2.3 to +0.3
2005 Top of Bank	1001.4 – 1001.2	+2.6 to +2.5

Evaluation of Project Success and Contributions to Improving Future Projects

The Sunriver Marina projects again exhibit the benefits of using whole trees oriented into the channel to promote sediment deposition and fish habitat creation. The upstream site appears to still be experiencing bank erosion. At the downstream site, the sloped low terrace is better protected by the placed wood. Trapped sediment is being colonized by sedges near the toe of the sloped low terrace. Planting more sedges and willow cuttings at the appropriate elevations would speed the stabilization of the deposited sediment. The large wood also provides the most diverse microhabitats in the reach. Again, trees oriented 45° to 90° to the channel, and extending into the low flow channel, provide fish habitat over all flows.

4.10 Project Review Summary

Eleven bank stabilization and fish habitat projects were reviewed to determine how projects are currently functioning relative to the original project goals. Projects typically had the same three goals: reduce bank erosion and sediment delivery to the river, improve aquatic habitat, and influence sediment deposition on the channel margin. Project tasks varied by site but generally included the following:

- Shaping eroding banks or terraces to reduce bank erosion, improve stability, and prepare sites for revegetation.
- Placing whole trees parallel and perpendicular to the channel to provide bank protection, aquatic habitat, and influence sediment deposition. Trees were usually placed individually rather than in aggregations.
- Anchoring trees with large rock, cables, or by placing the tree in contact with the channel or banks to increase friction in order to retain trees.
- Planting willow cuttings or other containerized vegetation in the project area.

Bank or terrace shaping is important for reducing erosion, increasing placed tree stability, and promoting vegetation success. Shaped banks appeared to be more stable and usually had better vegetation recruitment than steeper terrace faces. Constructing a floodplain surface emulating nearby reference floodplain features would improve vegetation colonization and increase the probability of long-term project success.

While individual trees protect banks, provide aquatic habitat, and influence sediment deposition, woody debris jams appear to be more stable structures that have a greater influence on downstream sediment deposition. Jams capture woody debris, promote scour, and form complex aquatic habitat. Extensive sediment deposits formed downstream of three substantial debris jams reviewed in the La Pine State Park reach.

Placed trees appeared to be relatively stable independent of the anchoring method. Cabled trees appeared to be the most stable. When done correctly, cables were difficult to see and the wood looked natural. Placing trees so that the majority of the stem contacts the channel bed or bank was also effective in maintaining stability. Trees placed on steep slopes or with a minimal portion of the stem in contact with the bed were less stable. Similarly, trees with large branches appeared to be more stable and had a greater influence on sediment deposition and fish habitat creation.

Vegetation conditions associated with projects was typically poor, especially when floodplain benches were not built adjacent to the treated bank. The large annual fluctuation in river stage creates a difficult situation for planting vegetation. Future projects should use adjacent floodplain areas as templates for determining appropriate elevations for planting sedges, willows, and upland vegetation. A predictable pattern was seen throughout the system whereby sedges inhabit the channel area near the high water stage; willows occupy an area about 0.5 ft to 1 ft above the sedge surface, and upland vegetation colonizes drier upland surfaces (Figure 4-17). Several of the projects either did not have a revegetation component or did not use reference vegetation conditions to guide planting.

Project location in the river network did not appear to have an overriding influence on channel margin sediment deposition aside from the three USFS sites downstream from Wickiup Dam. Bank erosion and instream sediment throughout the channel network appears to supply ample sediment available for channel margin deposition. Substantial sediment deposits related to woody debris were observed in the La Pine State Park reach.

Figure 4-17. Example reference riparian conditions on the Upper Deschutes River near the Sunriver Marina (left) and on the Fall River (right). Both sites exhibit the transition from the near-channel sedges to the upland conifers. Basing revegetation prescriptions on these species set at appropriate elevations is important for long-term vegetation survival.

Project location similarly influenced aquatic habitat. Downstream of Wickiup Dam, storage period flows are so deficient that even large whole trees do not interact with the low flow channel. With contributions from tributary streams, greater flows increase the low flow habitat volume in the Upper Deschutes River. Constructed projects should incorporate whole trees that intercept the low flow channel to enhance aquatic habitat during the critical winter period.

5.0 Bank Stabilization and Aquatic Habitat Improvement Project Design

5.1 Lessons from Reviewed Projects

The following section includes a final review of the evaluated projects and presents information that should be used for designing future projects.

5.1.1 Project Size

Reviewed projects ranged in size from small and localized (Rotz property) to treating a moderate length of the river (La Pine State Park). Future opportunities will likely reflect a similar range of projects. While reach-size projects are typically promoted as a means for addressing river processes (e.g. large woody debris recruitment) rather than just symptoms (e.g. bank erosion) of a river out of equilibrium, restoration efforts should evaluate projects of all sizes in order to address bank erosion and aquatic habitat conditions.

At the largest scale, addressing water management should be the top long-term goal of restoration efforts in the Upper Deschutes River. Reducing summer time flows and increasing storage period flows is critical to improving the ecological and physical processes of the river corridor. As mentioned previously, the overriding goal of this effort should be to manage the Upper Deschutes River's flows to resemble the historical hydrograph. Emulating the historical system over time will improve aquatic habitat, increase fish populations, re-establish riparian communities, and decrease bank erosion thereby improving water quality. Continuing to operate the river as an irrigation canal will perpetuate the current impairments.

The intermediate reach scale offers opportunities to address sections of the river with the understanding that the river's flows may change over time as water management modifications are implemented. An appropriate approach to identifying reach scale projects would be to assess the river network and determine where restoration opportunities exist. Potential high priority sites might include areas where channel avulsions threaten to cut-off meanders. Meander cut-offs lead to channel shortening, increased stream energy, and greater erosion potential. Reach scale projects should address both the cause and the symptoms of the river instability. For example, levee placement or channel dredging may have promoted channel straightening or increased bank erosion. Correcting the cause of the channel avulsion, if possible, as well as stabilizing the avulsion channel could halt meander abandonment and the resulting cascade of channel degradation processes. These efforts typically require both active and passive restoration. While such projects tend to be more costly than local scale projects, addressing river instability at the reach scale can also have great benefits.

Stabilizing short sections of eroding banks exemplifies a localized treatment. Numerous bank erosion sites on the Upper Deschutes River are the result of land management practices. Stabilizing these sites long enough for vegetation establishment would improve long-term stability and reduce sediment delivery to the river. Although these projects tend to have a higher per foot cost than larger reach projects, addressing bank erosion at individual sites is productive for addressing water quality, riparian vegetation, and aquatic habitat

In short, changing how the Upper Deschutes River is used for conveying irrigation water should be the ambition of resource managers in the basin. Reach and localized treatments should be evaluated for providing intermediate improvements for water quality and aquatic habitat. Taking a broad view of projects and how they fit into the overall picture of how the Upper Deschutes River functions is suggested.

5.1.2 Project Designs

Reviewed projects ranged in complexity. While several projects introduced wood to the river corridor without specific designs, other projects were prepared with more detail. The initial step in the design process should be to establish project goals and objectives, these then drive the rest of the design and implementation process. If the goal is to add wood to the river to increase the density of large organic matter, then randomly adding wood to the river would satisfy that goal. However, if the project goals include increasing diverse low stage fish habitat, promoting sedge growth along channel margins, and stabilizing an eroding terrace, then more detailed design information would be required. A site survey should be conducted to evaluate existing site and reference site conditions. Important information might include vegetated floodplain elevations, high stage and low stage flow vectors into the project area, water depths and water velocities over the hydrograph, and the potential for future woody debris recruitment. Because elevation is critically important for establishing sedges and setting woody debris structures, project construction should be completed by an experienced operator overseen by a knowledgeable restoration practitioner.

Project design should also implement both active and passive restoration techniques. Although many sites are likely to benefit from planting alone, installing large wood and shaping banks will be necessary to achieve more complex project goals. To affect more immediate results, building structures that emulate naturally-occurring features (e.g. debris jams) rather than just placing wood in the system and waiting for it to naturally form structures is recommended. Deploying large equipment and working in the river is typically necessary to complete such a project.

Restoration practitioners are advised to use reference conditions as part of the design process. Reference reaches are beneficial for evaluating riparian conditions, channel habitat units, instream structure (e.g. woody debris), and channel morphology. Although substantially smaller than the Upper Deschutes River, Fall River is a scaled version of the Upper Deschutes River's likely historical condition. Lower Fall River has exceptional bank stability, vegetation condition, and complex aquatic habitat. Dozens of juvenile fish were seen in the reviewed reach. Evaluating river corridor conditions in the Fall River may provide practitioners with ideas on improving habitat in the Upper Deschutes River.

In summary, the resource managers should establish project goals and objectives at project inception. The project's goals then drive project complexity and the need for detailed survey and design information. Larger scale or more intricate projects will likely necessitate topographic surveys as well as a thorough analysis of existing and reference site conditions. While these efforts are typically more expensive to implement, greater benefits should also be expected.

5.1.3 Projects as Learning Opportunities

Restoration projects can be complicated and daunting depending on the project's size and goals. Because projects are expensive and failure is looked down upon by funding and permitting agencies, practitioners are typically reluctant to institute new ideas and instead rely on practiced techniques. This approach squelches creativity and ensures that old ideas are perpetuated at the expense of innovative experimental methods. Practitioners should not only draw on others' experience for new ideas, but should also challenge themselves. Every project should include at least one design component that is experimental, yet one that emulates a natural process. Additionally, the projects must be monitored to evaluate the project components that were both successful and failures. Failures should not be criticized but registered as a learning experience and corrected.

For the Upper Deschutes River, one experimental component would be to construct engineered debris jams to provide bank stability, aquatic habitat, and sediment deposition. Natural jams seen in the La Pine State Park reach provide examples of stable structures. If debris jams achieved the project goals, they would provide a naturally-appearing and cost effective alternative to blanketing an entire meander with large woody debris. Combining a floodplain bench and a comprehensive revegetation plan that accounts for planting elevations would also be important. For all projects, establishing dense riparian vegetation at the floodplain elevation should be the standard for determining long-term project success.

6.0 Example Restoration Plan

The following section presents a plan for addressing bank erosion, aquatic habitat, and riparian vegetation conditions at sites characterized by eroding banks. A modified plan could be used for buffering vertical terraces. These treatments are more aggressive than placing whole trees in the river, but are expected to facilitate the processes created by naturally forming large woody debris jams. The following information was provided in the report *Deschutes River – Sunriver Marina Project Area Riparian Restoration Plan* (River Design Group, 2004).

6.1 Plan Overview

The example plan incorporates both active and passive techniques that are intended to influence near-bank shear stress, channel margin sediment deposition, riparian vegetation success, and aquatic habitat enhancement.

The proposed treatments are designed to decrease sediment delivery to the river by addressing the variables that attribute to accelerated bank erosion (Table 6-1). These variables include: 1) bank height ratio, 2) rooting depth ratio, 3) bank surface protection, 4) bank angle, and 5) hydraulic forces.

Table 6-1. Variables influencing bank erosion rates and design criteria to reduce bank erosion.

Bank Erosion Variable	Design Criteria
Bank height ratio	- Excavate existing bank to reduce bank height and improve planting conditions
Rooting depth ratio and density	- Sod mats - Sedge plugs for sloped bank - Willow cuttings and containerized plants at design floodplain elevation based on nearby reference floodplain elevation
Bank surface protection	- Woody debris structures - Revegetation (sod mats, woody riparian shrubs)
Bank angle	- Excavate existing bank height and slope the bank toe - Construct floodplain bench to buffer terrace toe
Aquatic habitat	- Woody debris structures interacting with channel to provide habitat during all stages - Riparian vegetation
Hydraulic forces - Velocity gradients - Near bank stress - Promote sediment deposition along channel margin	- Woody debris structures - Bank sloping - Revegetation

6.2 Floodplain Bench

Modifying the site conditions to promote riparian vegetation colonization is necessary to stabilize eroding banks. Constructing a floodplain bench is recommended for reducing the excessive bank heights. Benches should extend 10 ft to 12 ft from the eroding bank or terrace edge, or from the toe of a re-graded terrace face. Where practical, floodplain bench construction should follow this sequence:

1) Remove overlying sod and stockpile.
2) Over-excavate the floodplain to the design bench elevation.
3) Slope the remaining vertical bank face to moderate the bank slope.
4) Incorporate large woody debris structures as appropriate.
5) Replace previously excavated sod mats.
6) Plant native species including sedges on the lower bank and willows on the floodplain bench.
7) Out-haul excavated material to a designated stockpile location if necessary.

Floodplain benches lower the bank height relative to the water surface elevation, increasing riparian vegetation survival and productivity (Figure 6-1). Incorporating woody debris structures in combination with a comprehensive revegetation plan improves bank stability and aquatic habitat diversity.

Figure 6-1. An example of a floodplain bench constructed on a low gradient sinuous river in northwestern Montana. The preconstruction condition was dominated by a high eroding terrace (left). The terrace was sloped and a floodplain bench was built at the toe of the terrace (right). The post-construction photo was taken 2 years after construction.

6.3 Woody Debris Structures

Woody debris structures jams are designed to deflect the stream flow away from the bank, promote sediment deposition along the bank margin, and provide aquatic habitat (Figure 6-2). Structure spacing is dependent on structure size and site characteristics. Material should be collected near the site to minimize transport costs and to maintain the natural aesthetics of the structures. Recommended materials include large woody debris, small woody debris, and large rock for anchoring the woody material in the bank. Large rock should be buried below grade to improve structure aesthetics. Anchoring cables may be necessary to augment structure stability.

Figure 6-2. Two examples of woody debris jams in eastern Washington (left) and western Montana (right). Structures are anchored to reduce material loss.

6.4 Revegetation

Revegetation is an integral component to the long-term stability and aesthetics of the project site. Sod mats (if present) excavated during construction should be stockpiled at the project area for transplant following bank excavation and sloping. Sod mats provide a relatively rapid means for revegetating the excavated bank and speed vegetation colonization. Willow cuttings and containerized stock are also recommended for planting on excavated banks as well as sloped terraces. Cuttings should be a minimum of 3 ft in length. Containerized plants would include willows, alder, aspen, and upland species. Plants would be planted in clusters to emulate natural riparian communities.

Harvesting willow clumps from a donor area speeds floodplain bench stability. A native wetland seed mix may also be interspersed with the sod mats. A native upland seed mix is suggested for drier disturbed surfaces. Treating noxious weeds for a minimum of two years following construction may be necessary to prevent weed infestation of disturbed surfaces.

6.5 Summary

In summary, this generic restoration design presents a foundation for developing restoration plans for the Upper Deschutes River. The design components use native materials to address bank erosion, aquatic habitat, and riparian vegetation conditions. Although the severe annual water level fluctuations of the river present restoration challenges, the relatively low energy river system offers resource managers opportunities to enhance river corridor conditions.

7.0 References

River Design Group, Inc. 2004. Deschutes River – Sunriver Marina Project Area Riparian Restoration Plan. Prepared for the Upper Deschutes Watershed Council. 16 pp.

Yake, K. 2003. Upper Deschutes Subbasin Assessment. Prepared for the Upper Deschutes Watershed Council. 271 pp.